FRILL TREATMENT

with 2,4,5-T and 2,4-D effective for killing northern hardwoods

by W. E. McQuilkin

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A NEW METHOD

IN 1951, Chaiken (5)[1] reported successful use of a 1 percent water emulsion of 2,4,5-T, applied in ax frills, for killing unwanted hardwoods in the southeastern Coastal Plain. Chaiken's work was an important and, in large part, original contribution; it aroused a good deal of interest among foresters concerned with stand improvement, and it spurred further investigation of frill techniques in several other forest research centers.

Because accumulating evidence had indicated as early as 1951 that trees respond to ammate somewhat differently in the North than in the South, it seemed prudent and desirable to ascertain experimentally whether this new method of 2,4,5-T in frills would work as well in the North as Chaiken reported it did in the South. That was the primary motivation for the tests reported below.

Since our experiments were started in 1952, reports on several other more or less similar tests have appeared, all apparently having been inspired independently by Chaiken's paper. Tests in Michigan and Maryland--to be cited and discussed later--are of particular interest in relation to the present work because the three investigations had several features in common, and yielded results that are substantially in agreement. Inasmuch as reports on the Michigan and Maryland work have been published, our basic findings cannot now qualify as new information. However, our publication is justified (1) by the somewhat broader scope of our experiments; and (2) by our going beyond the bare reporting of results to correlate the agreements and attempt to reconcile the apparent disagreements in the findings of the different studies. This, we believe, considerably strengthens the conclusions and recommendations of each study in the areas of general agreement.

[1]Underlined numbers in parentheses refer to Literature Cited, page 17.

WHAT WAS DONE, AND WHY

THE entire experiment, except for two small supplemental tests noted later, was begun in July 1952.

The application technique

used by Chaiken was complete ax frills. This was taken as the standard application method in this experiment. All ingrown bark at cavities and cracks was to be severed and forked trees were to be frilled either below the fork or separately above. In general the workmen observed these instructions satisfactorily. Solutions were applied from a gallon can equipped with a spout and a few inches of rubber tubing. Applications were generous to the point of overflow, and a second pass was usually made around each tree.

Solutions poured into frills obviously are in large part absorbed into the sapwood. A pertinent question arose as to whether better root kills would ensue if more absorption into the phloem were accomplished. Theoretically, better kills would seem likely because: (1) solutes in general move downward in the phloem, whereas most movement in the sapwood is upward; (2) translocation of chemicals to the stem base and roots presumably would enhance root-killing action; and (3) under some conditions, hormone-type chemicals seem to translocate in plants in association with the sugar solutions that normally are moving downward in the phloem during the growing season.

In an attempt to get greater absorption into the phloem, a "skinned-girdle" technique was designed. This involved shaving off the outer bark into, but not through, the living inner bark and phloem in a complete girdle about 6 inches wide. Skinning was done with a sharp light ax. Solutions were applied with a paintbrush.

The chemical

2,4,5-T, hereafter designated by "T", was recommended by Chaiken and was used here as the standard chemical. However, 2,4-D, hereafter designated by "D", is cheaper; and mixtures of D and T are widely used in brush control. So we ran parallel series of treatments with T and a mixture of D and T in the proportions of 2 to 1. All chemicals were in the form of butoxy ethanol esters.

The concentration

recommended by Chaiken was 1 percent by weight, or as better expressed in acid equivalent per hundred gallons (abbreviated ahg), 8 pounds ahg. This was taken as the standard concentration. A parallel series of treatments was made at 24 pounds ahg as insurance in the event that 8 pounds proved to be too weak for northern conditions. In addition, for the previously untried skinned-girdle applications, concentrations of 40 and 80 pounds ahg were included. Painting the girdles required much less solution than to fill the frills, so the more expensive high concentrations could reasonably be considered.

The carrier

recommended by Chaiken was water; but knowing that hormone-type herbicides usually are more potent in oil, we ran parallel series of treatments with both water and oil carriers. Diesel oil was used.

Treatment combinations

in the basic experiment, in which all variables are represented factorially, thus included 16 treatments: 2 application techniques X 2 chemicals X 2 concentrations X 2 carriers. The inclusion of two higher concentrations with the skinned-girdle technique added 8 more treatments, making a total of 24.

The test trees

available for this experiment were several hundred low-grade trees that had been marked for removal in a stand-improvement cutting in a compartment on the Pocono Experimental Forest in northeastern Pennsylvania. We were restricted to those marked trees and had to fit the experiment to them.

Out of the balancing of available trees against desired treatments, we were able to assign 12 beech trees, 12 red maples, 6 sugar maples, and 6 birches (yellow and black) to each of the 16 treatments in the basic experiment. For the 8 high-concentration skinned-girdle treatments, only 12 beeches and 12 red maples were available.

The trees ranged from 4 inches d.b.h. up to 16-inch or larger wolf trees, but the majority fell in the range of 6 to 10 inches. Approximately equal distributions of size classes of each species were assigned to each treatment. A typical 12-tree assignment to a treatment included:

Trees (number)	Size (inches)
1 or 2	4
3 or 4	6
3	8
2 or 3	10
1 or 2	12+

Total number of trees in the 24 treatments listed above was 768.

Supplemental tests

1. Basal spraying. To provide some indication of the efficacy of this method in comparison with the treatments in the main experiment, 12 beeches and 12 red maples were sprayed basally with T in oil at 24 pounds ahg, and a similar set of trees was similarly treated with the D-T mixture.

2. Ammate in notches. As with the basal spraying, 12 trees each of beech and red maple were treated by this method to provide an indication of comparative efficacy.

This test was expanded, however, to include September and November treatments as well as July treatments.

3. Other species. Scattered trees of gray birch, aspen, pin cherry, striped maple, and serviceberry had been marked for removal, but there were not enough of them for apportionment among all treatments. They were therefore all assigned to two of the frill treatments--T in water at 8 pounds ahg, and the comparable D-T treatment. The total was 46 trees.

4. Other seasons of treatment with T. A miscellany of 4- to 8-inch trees--124 in all--were left over from the above treatments. These were treated in November with the thought that some indication of the effect of season might be gained thereby. The trees were divided among 4 treatments, all with T at 8 pounds ahg, split between frill and skinned-girdle application, and between oil and water carriers.

Total number of trees in the supplemental tests adds up to 290, making the grand total for all tests 1,058.

WHAT WAS FOUND

THE final observations, upon which this report is based, were taken in the fall of 1955--three full growing seasons after treatment. Even then, the story is not entirely complete. Many of the trees still living exhibit signs of injury and may die in another year or so; some have wholly dead girdles and probably are hanging on through root grafts with healthy trees. The main experiment will be discussed first. Data will be presented as percents of kill.

The skinned-girdle

technique was definitely less effective than frills. Either the theory was faulty or the technique was poor. A recent

report indicates faulty theory. Studying translocation in marabu, a woody plant in Cuba, Hay (7) was unable to detect movement of T through the phloem after either basal-bark or cut-surface applications; all translocation of the chemical seemed to be through the xylem tissues.

In an overall comparison of skinned-girdle vs. frill application within the balanced factorial series of 16 treatments, the percents of kill were:

	Percent
Skinned girdles	43
Frills	78

Each of these percents is based upon 288 trees representing the four major test species: beech, red maple, sugar maple, and birch (yellow and black birches lumped as one).

The skinned girdles were especially poor with treatments in water carriers. When the two methods are compared for oil treatments alone, the difference is less, but the frill method still is definitely superior. The kill percents for oil alone, each based upon 144 trees, were:

	Percent
Skinned girdles	66
Frills	85

At the 40- and 80-pound ahg concentrations of chemical, which were not replicated in the frill series, the kills with oil on skinned girdles averaged 85 percent--equal to the frill results with the lower concentrations. However, since the skinned girdles show no advantages over frills, even at the high concentrations, and require more labor time to install, it is concluded that the method does not warrant further consideration. The remainder of the discussion of results will deal only with the frill method, except as stated otherwise.

Analysis of results

obtained from frill treatments was based on these factors: (1) chemical, (2) concentration, (3) carrier, (4) tree species, and (5) tree size. Table 1 gives the kills in percent by individual treatments for each species, and by several

Table 1.--Percents of kill for each species by individual treatments, and by various groupings of treatments

Treatments compared			Percent of kill				
			Beech[1]	Red maple	Sugar maple	Birches	All
D-T	Oil	8 lb. ahg	67	67	100	100	78
		24 lb. ahg	100	67	83	100	85
	Water	8 lb. ahg	54	67	100	100	73
		24 lb. ahg	92	58	67	100	78
T	Oil	8 lb. ahg	83	83	100	100	89
		24 lb. ahg	82	100	67	100	89
	Water	8 lb. ahg	42	33	67	83	50
		24 lb. ahg	100	50	83	100	81
All D-T			78	65	88	100	79
All T			77	67	79	96	77
All oil			83	79	88	100	85
All water			71	52	79	96	70
All 8 lb. ahg			61	63	92	96	72
All 24 lb. ahg			94	69	75	100	83
Oil (D-T and T)		8 lb. ahg	75	75	100	100	83
		24 lb. ahg	91	83	75	100	87
Water (D-T and T)		8 lb. ahg	48	50	83	92	62
		24 lb. ahg	96	54	75	100	79
All treatments			77	66	83	98	78

[1]One of the beech treatments involved only 11 trees because a tree was missed in the final tally; in another treatment a 13th tree was inadvertently treated and included. These discrepancies account for those percentage figures that do not fit a base of 12 or multiples thereof.

groupings of treatments for which comparisons are of interest. It should be kept in mind that the treatment units are 12 trees for beech and red maple, and 6 trees for sugar maple and the birches. Hence, as might be expected, the kill percents for individual species-treatment units show considerable erratic variation. The groupings, which provide larger bases for the percentage figures, are much more informative. The total number of trees represented in table 1 is 288--96 beeches, 94 red maples, 48 sugar maples, and 48

birches; consequently each percentage in the two-way groupings is based upon one-half of the appropriate one of these numbers, and upon one-fourth of the appropriate number in the four-way split.

Comment on the five factors follows:

1. Chemical. The two chemical formulations appear to be about equally effective, with a mean kill of 79 percent for D-T and 77 percent for T. This apparent equivalence is supported also by results in the skinned-girdle series. There the mean kills were 50 and 53 percent.

2. Concentration. The 24-pound concentration is somewhat more effective than the 8-pound rate, but not spectacularly so. The means are respectively 83 and 72 percent. The difference comes mainly from the water series of treatments, as shown in the last comparisons in table 1. In the oil series, the higher concentration resulted in only 4 percent additional kill--87 vs. 83 percent. Since, as pointed out in the next paragraph, oil seems definitely to be superior as a carrier, responses to concentration are of greater interest in the oil series of treatments. The small difference of 4 percent in favor of the higher concentration--so small that it may be nothing more than chance variation--does not seem to be enough to warrant the extra cost of the 24-pound rate.

3. Carrier. Kills with oil were consistently better than with water for both chemical formulations and all species. Mean kills are 85 and 70 percent. The difference of 15 percent is significant by chi-square test, which indicates chances of about 60 to 1 that it was a treatment effect. Although not spectacular, the difference is large enough to be important in stand-improvement work.

Results in the skinned-girdle series support the conclusion that oil is the more effective carrier. There the mean kills were 73 vs. 30 percent.

4. Species. The most striking species difference is the comparatively high sensitivity of the birches, which went out 100 percent or nearly so under all frill treatments. Red maple showed the lowest mean kill--66 percent--as compared to 77 percent for beech and 83 percent for sugar maple. However, the red maple mean was pulled down largely in the water series, as may be noted in the last comparisons in table 1. With oil treatments, which are of greater practical

interest, the differences between red maple, sugar maple, and beech appear to be nothing more than chance variation.

5. Tree size. Larger trees unquestionably were more resistant in these tests than smaller trees. However, some confounding with vigor may be involved, as the larger trees typically were dominants or co-dominants, whereas many of the smaller trees were intermediates or suppressed. Since there is no way to segregate size and vigor in the present data, the relationship of tree size to kill is shown in table 2 with the general qualification that confounding may be present.

Table 2.--Relationship between tree size and percent of kill

(Basis: 288 trees in 8 frill treatments, including both carriers, both chemicals, and both concentrations.)

Species	D.b.h. 4-6 inches	D.b.h. 8-10 inches	D.b.h. 12+ inches
Beech	88	72	38
Red maple	95	45	44
Sugar maple	93	75	60
Birches	96	100	100
All species	92	68	51

The skinned-girdle series shows the same general relationship as appears in table 2. When the oil series is segregated from the totals in table 2, the same relationship prevails but, as might be expected, the drop-off of kill with tree size is not so steep. Mean kills with oil for the three size categories (all species) were 97, 78, and 63 percent.

The supplemental tests

1. Basal spraying. Kills were about on a par with those from oil treatments in frills. For beech, 7 of 12 trees were killed by the D-T spray, and 12 of 12 by the T spray--a species mean of 79 percent. For red maple the respective figures were 9 and 10 trees killed, mean 79 percent. The mean for D-T was 67 percent, and for T, 92 per-

cent. However, 24 trees is too small a base to warrant attaching much weight to this difference.

Inasmuch as these basal sprays gave no better results than frill treatments, and are more costly in materials, as Chaiken has pointed out, there is no reason to recommend them for treating plants of tree stature.

2. Ammate in notches. This supplemental test, which also involved a test of the effect of season, has been reported elsewhere (10). Suffice it to note here that the ammate-notch method gave practically 100-percent kills when applied during the growing season, but poor results in November applications. Ammate acts more quickly than the hormone-type chemicals. Browning often occurs within a few weeks after application; and if the tree is destined to die, it will either be dead or will bear only an insignificant amount of foliage the next year.

The disadvantages of the ammate-notch method, as compared to T or D-T in frills, is its considerably higher cost in both labor and materials.

3. Other species. The several minor weed species (gray birch, aspen, pin cherry, service berry, striped maple) all were taken out 100 percent by the water applications in frills with T or D-T at 8 pounds ahg. Though the numbers of trees of each species ranged only from 3 to 19, the evidence was quite convincing that, when growing as understory trees, all these species are highly sensitive to treatment. It is possible that open-grown trees would exhibit more resistance.

4. Other seasons of treatment with T. Indications from this test are that November treatment is less effective than July treatment. Of 23 beeches and red maples frill-treated with T in oil at 8 pounds ahg in November, only 12 were killed, or 52 percent. And these were all smallish trees--8 inches d.b.h. or less. Trees of this size went out almost 100 percent with the same treatment applied in July. The other November treatments gave results of about the same magnitude.

Though admittedly not a conclusive test of seasonal effect, the evidence obtained definitely favors treatment during the growing season. Thus the seasonal relationships for frill treatment with T or D-T, and for notch treatment with ammate, appear to be similar. Dormant-season frill

treatment with T or D-T in this region certainly should be done only on a trial basis until more evidence is at hand.

DISCUSSION & CONCLUSIONS

SINCE the initial motivation for this study was to test Chaiken's method--T at 8 pounds ahg in water in frills --the results will first be considered from that point of view. The conclusion is that, using water carrier, the method is not satisfactorily effective in northeastern Pennsylvania. With oil carrier it is fairly effective, but it still falls considerably short of the results that apparently can be obtained on the southern Coastal Plain.

Basic agreement

was found in the northern results. The Pennsylvania results mentioned above are in accord with results from the Michigan and Maryland studies (2, 3, 8). At both these places frill treatments with T in oil and in water carriers were compared, and oil gave definitely better results. Water treatments therefore would seem to have little place in the North except possibly in rare situations where only highly sensitive species like birch or aspen were to be killed.

There is fairly good, though not complete agreement on concentration of chemical. The findings of Little and Mohr in Maryland (8) and our own findings concur with Chaiken's recommendation of 8 pounds ahg. Little and Mohr, however, obtained almost as good kills with 4 pounds; we tried nothing lower than 8 pounds. Arend and Coulter in Michigan (2) tried concentrations from 4 to 40 pounds ahg, and recommend the 4-pound rate. From the evidence at hand, it would appear that choice between the 4- and 8-pound rates is not very sharply defined. Further experience may lead to rather general adoption of the 4-pound rate; certainly there

is good agreement that rates higher than 8 pounds ahg are not worth the extra cost.

In our experiments, a D-T mixture proved to be as effective as straight T. Grano (6) reported water emulsions of D-T and T to be about equally effective on southern red oak in Arkansas. No other comparisons of these two formulations when applied in frills have come to our attention. Since the mixture is somewhat cheaper, the evidence that it is equivalent to straight T in frill treating has practical significance, and justifies further trial.

Effect of season

of treatment on kills is not well established. Very likely the effects of season vary with species and climate, and perhaps also with height of frill above ground. Listed below are different reports bearing on the effect of season:

Chaiken: says treatment during growing season may be more effective, but that good kills were accomplished by dormant-season applications.

Present study: definitely poorer results from dormant-season treatment of beech and red maple.

Arend and Coulter: report good control of oaks, aspen, and red maple at any season.

Little and Mohr: no seasonal comparisons; test treating done in January, species predominantly oaks, with good results. Red maple, however, reported to be relatively resistant.

Martin and Rogers (9): report "year-round effectiveness" in Missouri; however, they frilled close to the ground, used 16 pounds ahg, and the species probably were mostly oaks--all of which are factors that would predispose towards high kills.

It appears that oaks may be successfully treated at any season. Chaiken notes that the oaks are among the more susceptible species. Little and Mohr's good average kills after winter treatment were mostly oaks. Probably oaks were predominant in the stands where Martin and Rogers, and Arend and Coulter, accomplished good kills with winter treatment.

Red maple, on the other hand, gives evidence of greater resistance to winter treatment than to summer treatment according to both Little and Mohr's observations and our own. However, in their red maples, the resistance was expressed mainly in delayed mortality--most of the trees eventually died--whereas only about half of our trees were dead 3 years after November treatment. In apparent disagreement, as regards maples, is the report of Arend and Coulter. Their statement that "all trees had dead tops by the end of the first growing season regardless of season of year" does not accord with either our experience or that of Little and Mohr. We do not get such quick kills, even with summer treatment. Possibly Arend and Coulter's maples were small or low-vigor trees; they give no data on these points. Concerning beech, only Chaiken has mentioned it specifically in connection with frill treatments with T; he rates it among the more resistant species, which accords with our poor results with beech after winter treatment.

Insofar as the available evidence can be interpreted, treatment during the growing season would seem advisable in the Northeast as holding the greatest assurance of success with red maple and beech. With oaks and such sensitive species as the birches and aspens, seasonal restrictions probably can safely be relaxed. More tests and experience are needed to clarify these seasonal relationships.

Size of tree

is not recognized as an important factor by either Chaiken, Little and Mohr, or Arend and Coulter. A recent note on frill treatment of oaks and hickories in Georgia, using T in water, asserts that tree sizes from 2 to 21 inches d.b.h. did not affect mortality (4). Yet our tests yielded pretty strong evidence of increasing resistance with increasing size, and a similar relationship was observed by Martin and Rogers in Missouri (9) and by Roy on tanoak in California (11). Roy states that the relationship holds regardless of crown class.

Here again, as with season of treatment, contradictory observations doubtless have come about through the confounding effects of different species and conditions. With resistant species or under conditions that favor resistance, large trees may be expected to exhibit more resistance than small trees; whereas with sensitive species or conditions

favoring susceptibility to treatment, effects of tree size may be masked by high percents of kill among all sizes.

Basal resprouting

after top kill was not in accord with results obtained in the South. Chaiken reported "absolutely no resprouting" from properly frill-treated trees. This certainly does not hold in the North. Some resprouting was observed in our experiments, but we were unable to get good data because the sprouts were all closely browsed off by deer. The general impression was that only a minority of the treated trees were resprouting, that most of these were red maple, and that the sprouts were weak.

Little and Mohr's data show 33 percent of their trees resprouting; and Arend and Coulter report about 50 percent, but state that the sprouts were weak. Later Arend (1) found that sprouting was less after late summer to fall treatments than after winter or early spring treatments. Also, that placing the frills near the ground reduced sprouting, as compared to frills at waist height.

A fair statement might be that, in the North, frill treatment with T reduces the number and vigor of sprouts, as compared to simple cutting or girdling without chemicals, but that the treatment by no means eliminates sprouting.

No cost data

were obtained in our experiment. According to Chaiken, frill treatment with T is substantially cheaper than basal spraying, ammate in notches, or double-hack girdling without chemical. He shows a cost per 10-inch tree of 3 cents for frill treatment and 7.1 cents for ammate, with labor at 75 cents per hour. Adjusting for labor at $1.25 per hour, and adding 1 cent per tree for use of oil in the frill treatment, these figures become respectively 5.2 and 8.3 cents per 10-inch tree. Weitzman and Lindahl (12) estimate the cost for ammate treatment at about 1 cent per inch of diameter. For a 10-inch tree, this would come to 10 cents, as compared to the 8.3 cents derived from Chaiken's data.

The significant point is that frill treatment with T costs somewhere in the range of one-half to two-thirds as much as the ammate notch treatment.

An action program in stand improvement, using T in oil in frills, had been applied by 1956 on about 2,000 acres in eastern Maryland. This work was started in a small way in 1953 (3) on the basis of southern and Lake States experience, and expanded in succeeding years as local test results became available. Costs are reported to be $13 to $15 per acre averaging about 385 trees with an average diameter of 6 inches (8). This comes to about 3.6 cents per tree which, when adjusted for tree size, agrees pretty well with the estimate of 5.2 cents derived above from Chaiken's data for a 10-inch tree.

SUMMARY & RECOMMENDATIONS

A METHOD recommended in the South for killing unwanted hardwoods--frill treatment with 2,4,5-T in water at 8 pounds acid per hundred gallons--was tested for northern conditions in northeastern Pennsylvania. Several modifications of the above treatment, and a series of treatments involving application to a skinned girdle, also were tested.

- The skinned-girdle method was not so effective as the frill method, and is dropped from further consideration.

- In frill applications, a brush-killer mixture of 2,4,5-T and 2,4-D was as effective as straight 2,4,5-T. Since the mixture is cheaper, its use on a trial basis is recommended.

- Concentrations of 24 pounds acid per hundred gallons were not markedly more effective than 8-pound concentrations. The 8-pound rate is recommended. Some cited tests by other investigators indicate that 4 pounds may be adequate for the more sensitive species.

- The chemicals were definitely more effective in an oil carrier than in water; this finding is supported by several other investigations in northern states. So oil is recommended. The use of oil instead of water is the major departure from Chaiken's recommendation in the South.

- Yellow and black birches, and the minor weed species--gray birch, aspen, pin cherry, striped maple, and service berry--were all highly sensitive to treatment, with near 100-percent kills. Beech, red maple, and sugar maple were more resistant. Cited works of others indicate that the oaks are more sensitive than the maples and beech.

- Beech and maple trees 12 inches d.b.h. and larger were distinctly more resistant to treatment than 8-inch and smaller trees. Not all investigators have observed this relationship. It probably shows up most conspicuously on the resistant beech and maples. When treating larger trees of these species, an extra-heavy dosage, by making several passes around the tree with the chemical solution, is suggested.

- November treatment was less effective on beech and maple than July treatment, but this seasonal effect is only partly supported by other northern studies. So, although winter treatment of these species evidently will sometimes succeed, treatment during the growing season is recommended as providing greater assurance of success. Other cited investigations indicate that oaks probably can be treated successfully at any season.

- Northern investigators agree that frill treatment with 2,4,5-T reduces basal resprouting as compared to simple girdling but, in contrast to southern experience, does not by any means eliminate it. Low placement of girdles and treatment during the growing season are reported to result in a minimum of resprouting.

- In a supplemental test, basal spraying gave approximately the same kills as frill treatment; but, since basal sprays are more expensive, they have little place in treating woody plants of tree stature.

- In another supplemental test, dry ammate in basal ax notches resulted in almost 100-percent kills in July and September treatments, but was markedly less effective in November. This ammate treatment, however, is 60 to 100 percent more expensive than 2,4,5-T in frills.

● With mixed species and sizes of northern hardwood trees, the present experiment has indicated that top kills of around 85 percent may be expected after frill treatment during the growing season with 2,4,5-T or a mixture of 2,4,5-T and 2,4-D in oil at 8 pounds acid equivalent per hundred gallons.

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